Jet Propulsion Laboratory
California Institute of Technology

Improved Content-Based Image Classifiers for the PDS Image ATLAS

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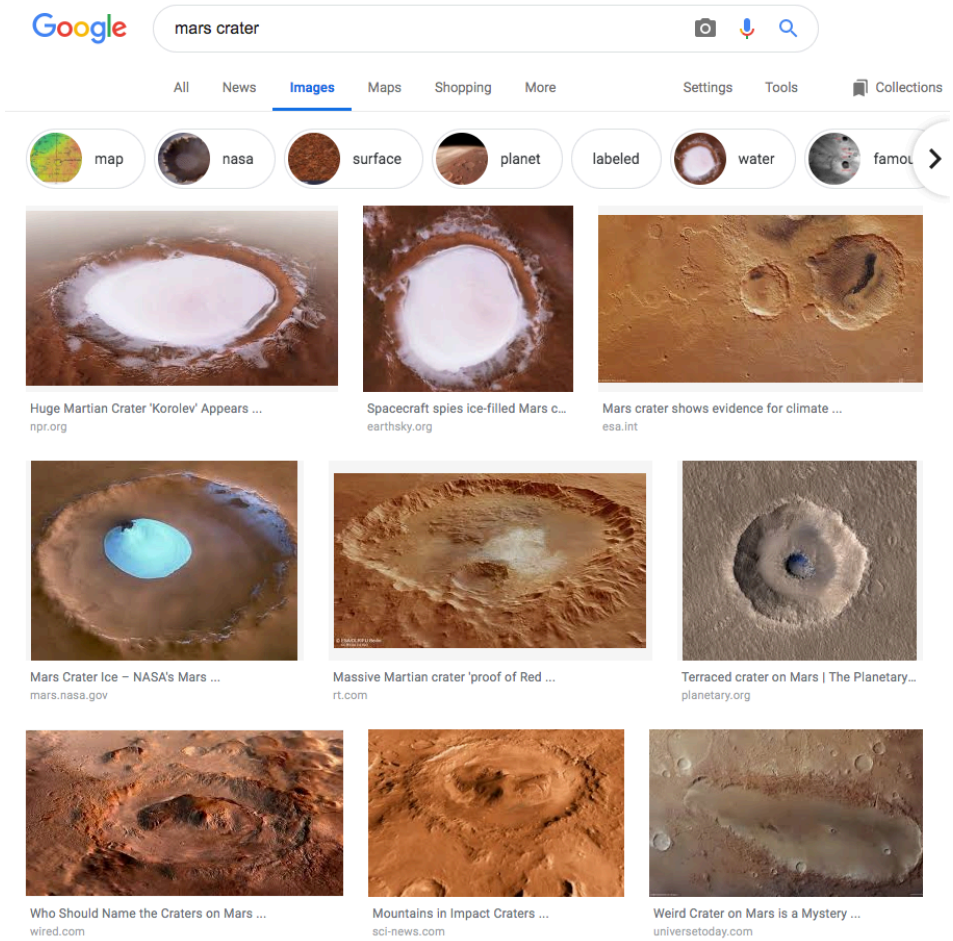
Current Mars Data Set Collections

- Surface Missions
  - 11.9M --- Mars Science Laboratory (MSL)
  - 7.1M --- Mars Exploration Rover (MER)
  - 1069 --- Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight)

- Orbital Missions
  - 3.0M --- Mars Odyssey
  - 1.9M --- Mars Reconnaissance Orbiter (MRO)

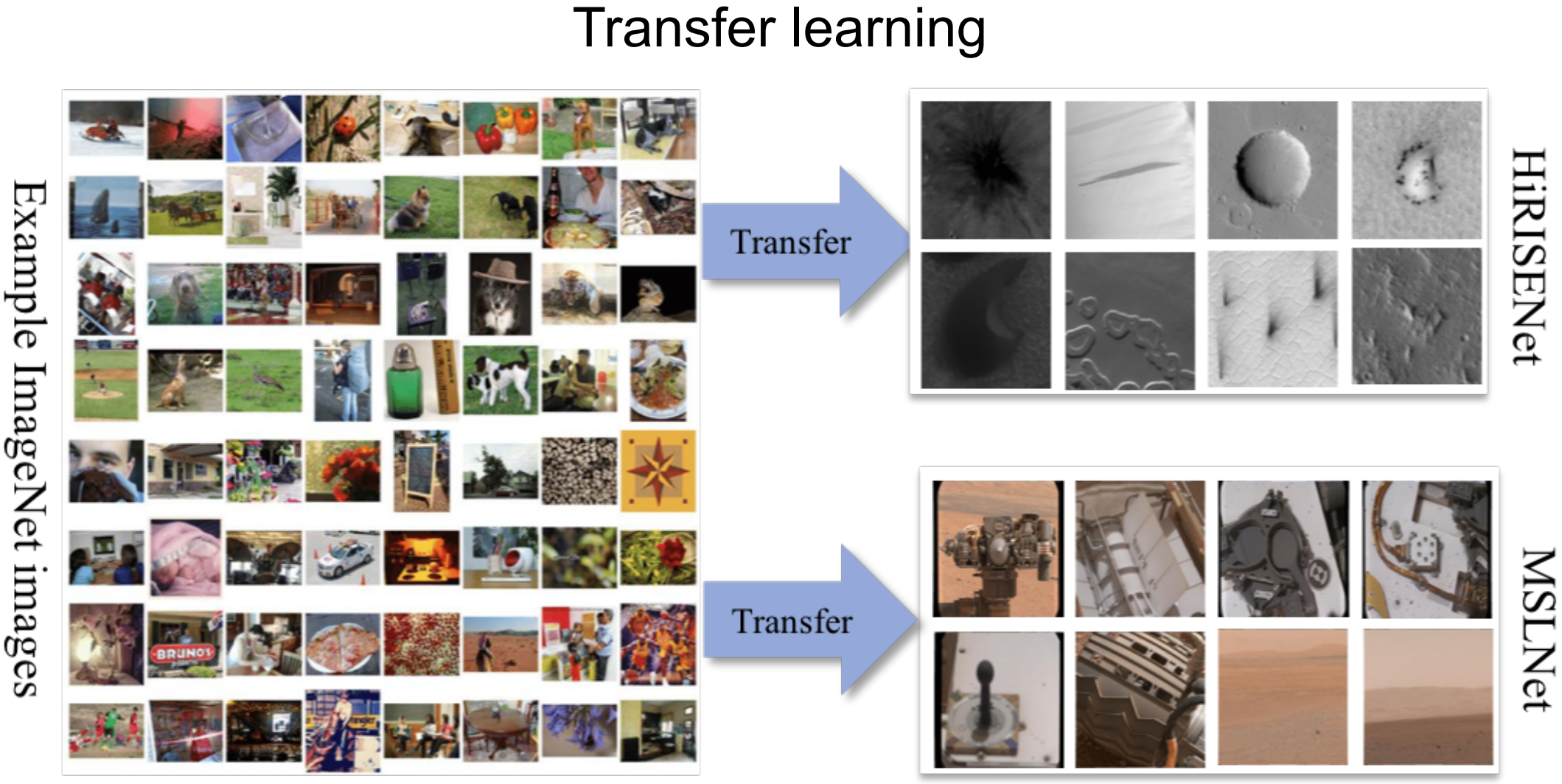
How to Find What You Want?

Google search



Manual examination

Machine Learning Solution

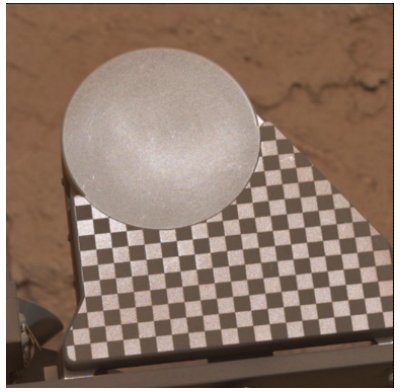


MSL Rover Data Set

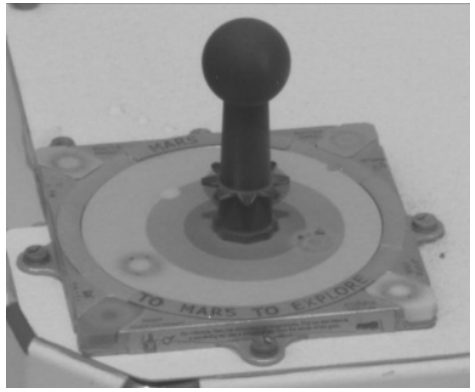
- 6691 labeled images
  - Collected from Mastcam Right eye, Mastcam Left eye, MAHLI
  - 3,746 training, 1640 validation, 1305 testing
  - 24 classes
  - Published under DOI 10.5281/zenodo.1049137

Drill hole

Wheel



Observation tray

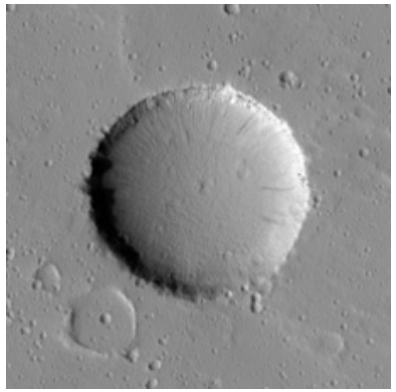


Mastcam cal target

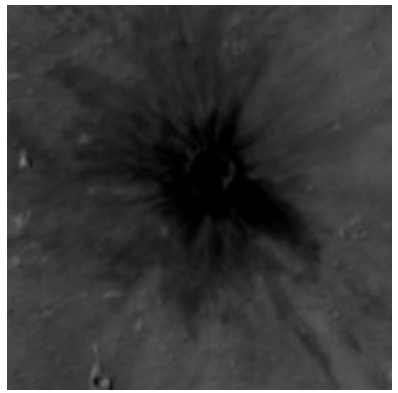
Example classes for MSL Rover data set. See full list at [Wagstaff et al, 2018, AIAA]

MRO HiRISE Data Set

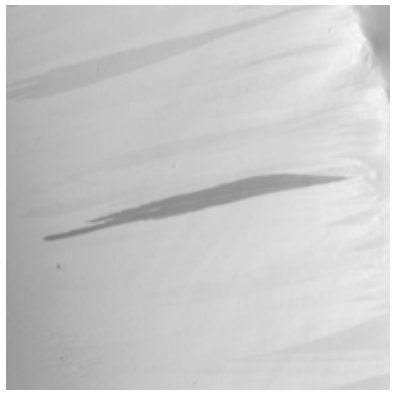
- 73031 labeled images
  - Collected from MRO HiRISE camera
  - 46970 training, 13391 validation, 1810 testing
  - 8 classes
  - Published under DOI 10.5281/zenodo.2538136



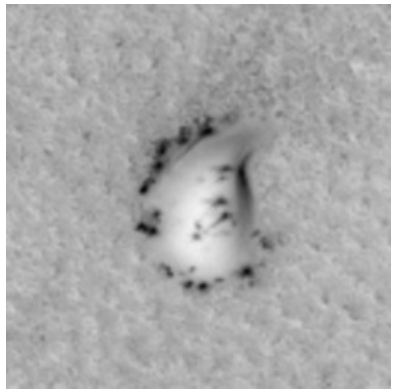
Crater



Impact ejecta



Slope streak

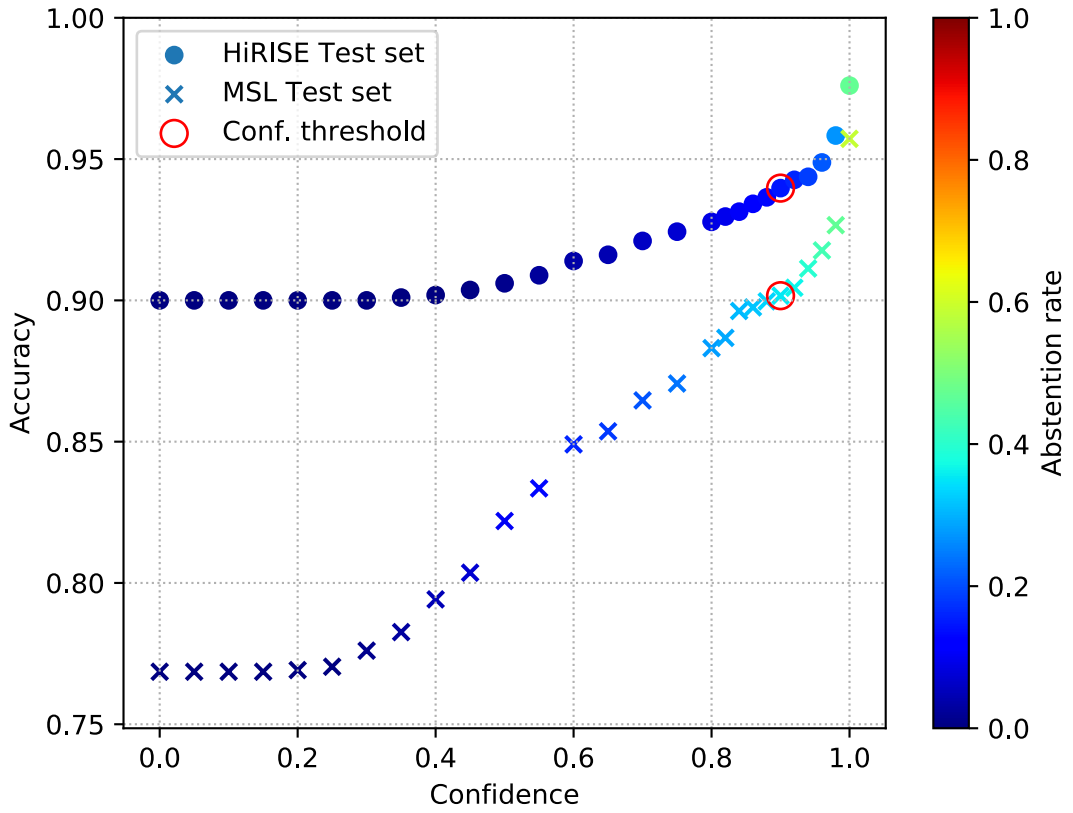


Bright dune

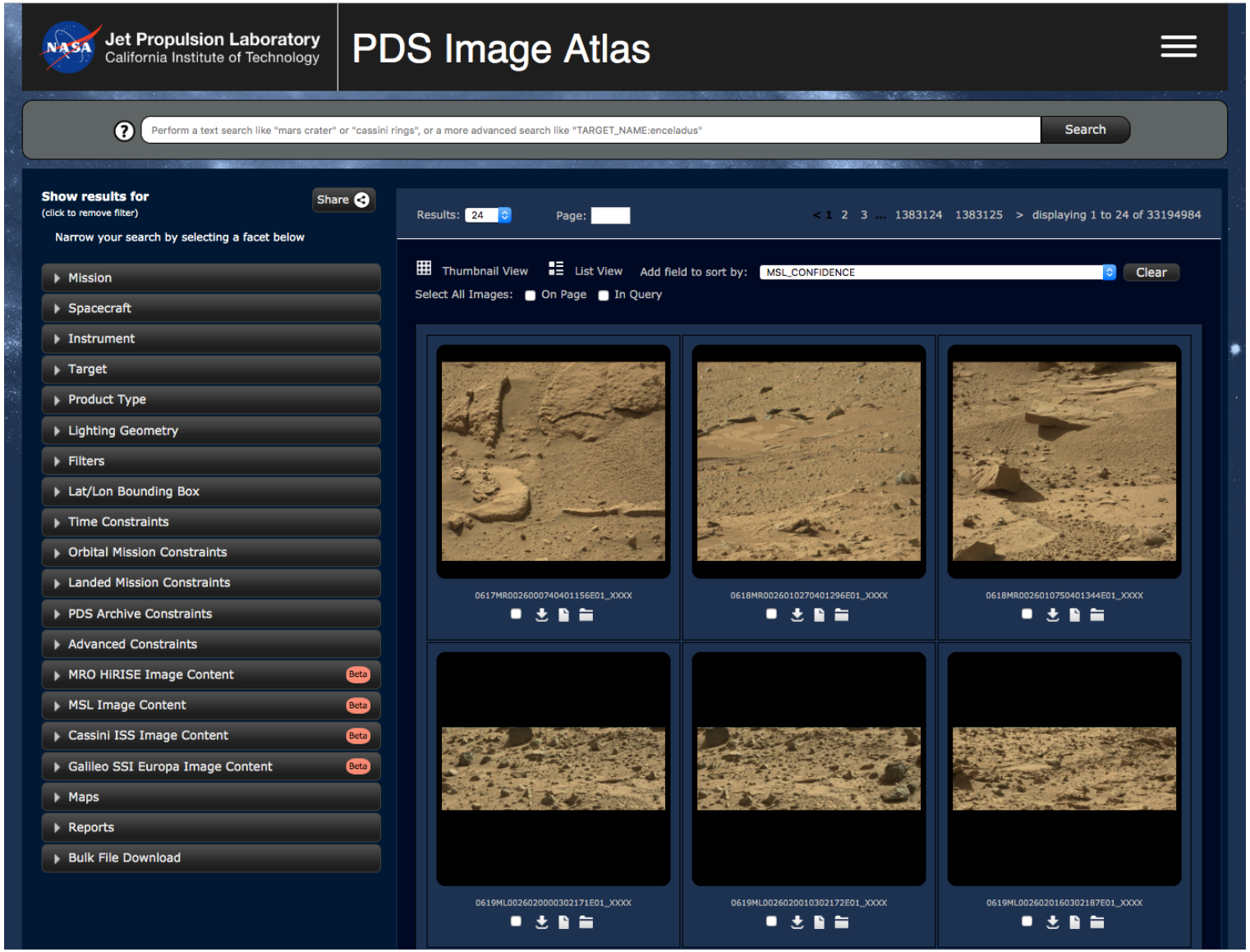
Example classes for MRO HiRISE data set

Evaluation

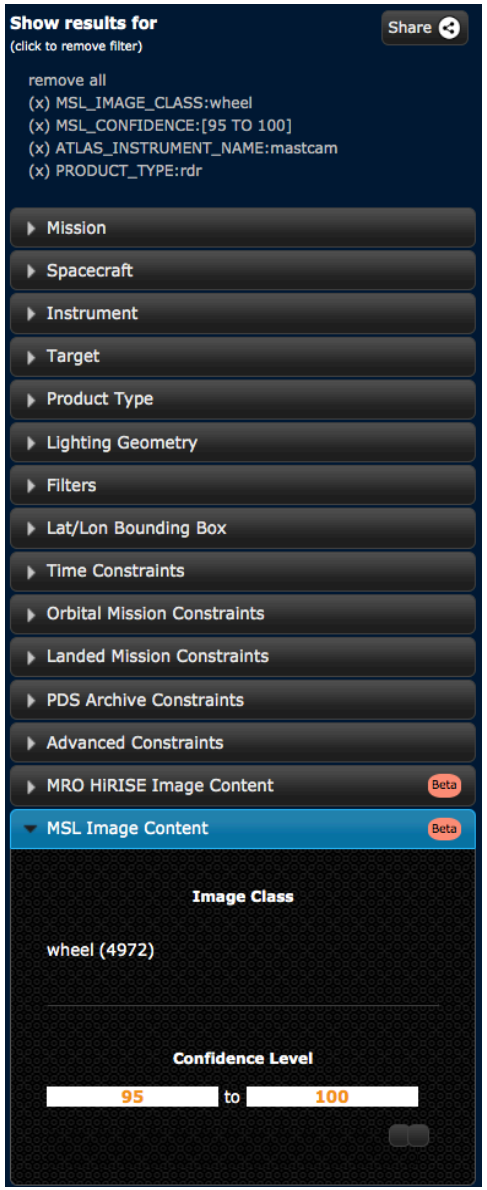
- Test set accuracy at 90% confidence
  - MSLNet: 76.9%
  - HiRISENet: 93.46%
- Test set abstention rate at 90% confidence
  - MSLNet: 35.3%
  - HiRISENet: 14.8%
- Classifier calibration
- Error analysis



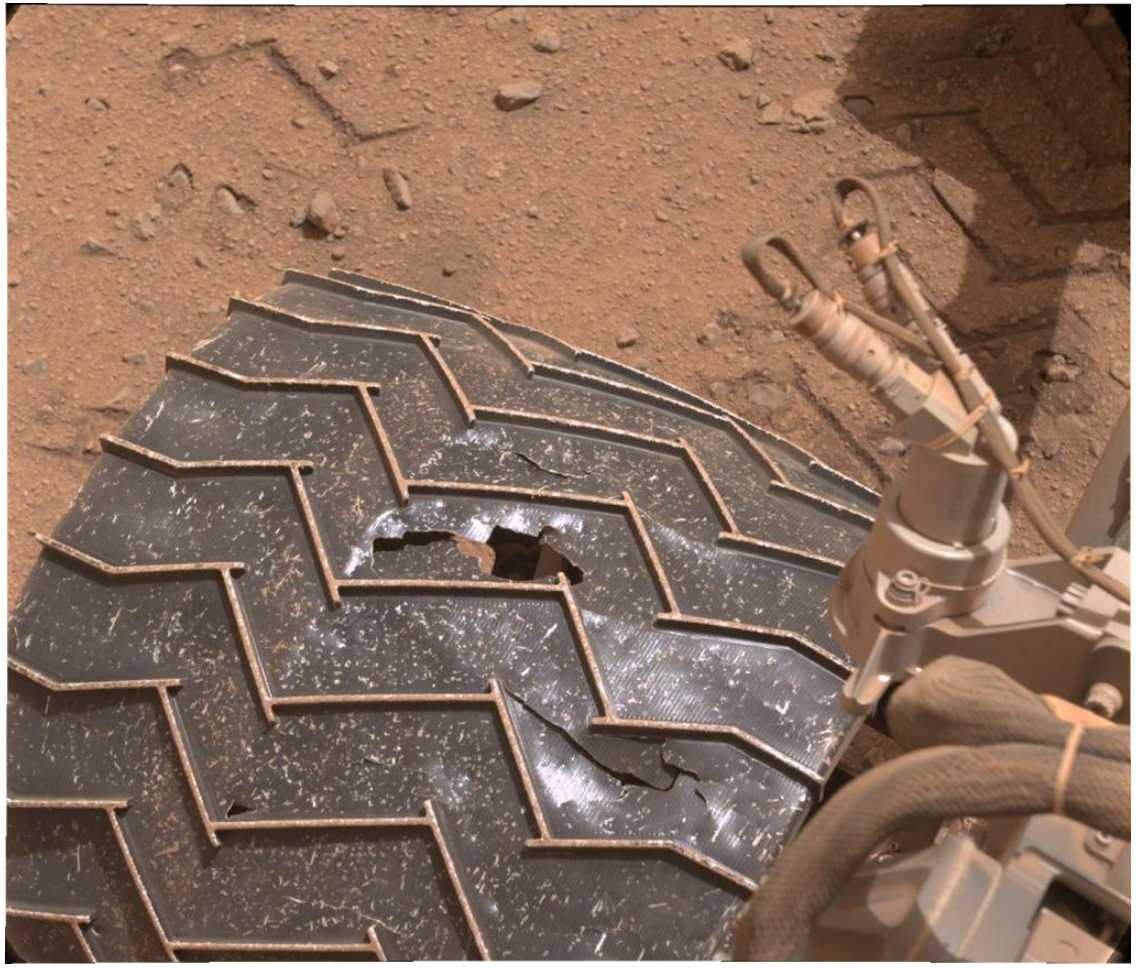
http://pds-imaging.jpl.nasa.gov/search/



MSL Rover Wheel Degradation



MSL Rover Wheel Degradation



July 2014

August 2017

Summary

You.Lu@jpl.caltech.edu

- Fine-tuning Earth-based CNN to adapt it for Mars images was successful
  - Despite differences in image properties, imaging conditions, classes of interest.
  - Results for Mars surface and orbital images
- Classification models were deployed on PDS Image Atlas
  - http://pds-imaging.jpl.nasa.gov/search/
- Future work:
  - Continue improving MSLNet and HiRISENet
  - Support more instruments

Funding: Planetary Data System (PDS), Multimission Ground System and Services (MGSS), JPL R&TD

Backup slides

MSL Rover Data Set

- Split by sols (Mars solar day)

	Train Sol 3 - 181	Validation Sol 182 - 564	Test 565 - 1060
Mastcam Left	1491	189	202
Mastcam Right	1935	94	373
MAHLI	320	1357	730
Total images	3746	1640	1305

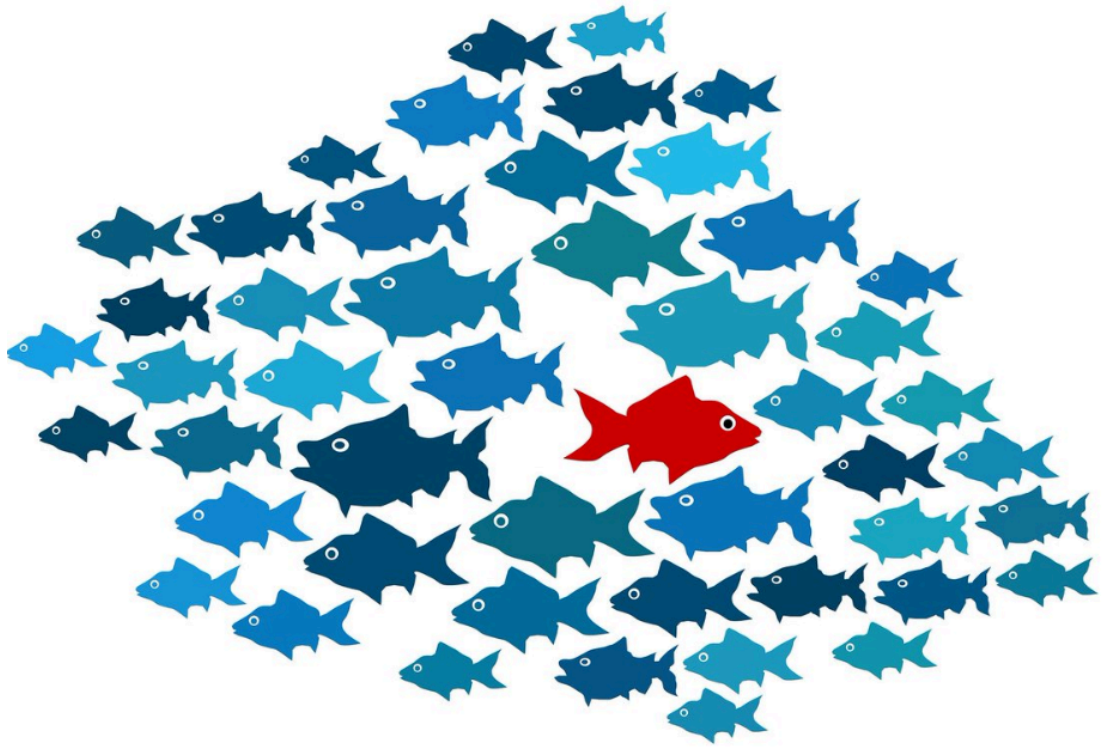
Table: MSL Rover data set by instrument and sol range

- This strategy was chosen to model how the system will be used operationally with an image archive that grows over time. The images were collected from sols 3 to 1060 (August 2012 to July 2015).

MRO HiRISE Data Set

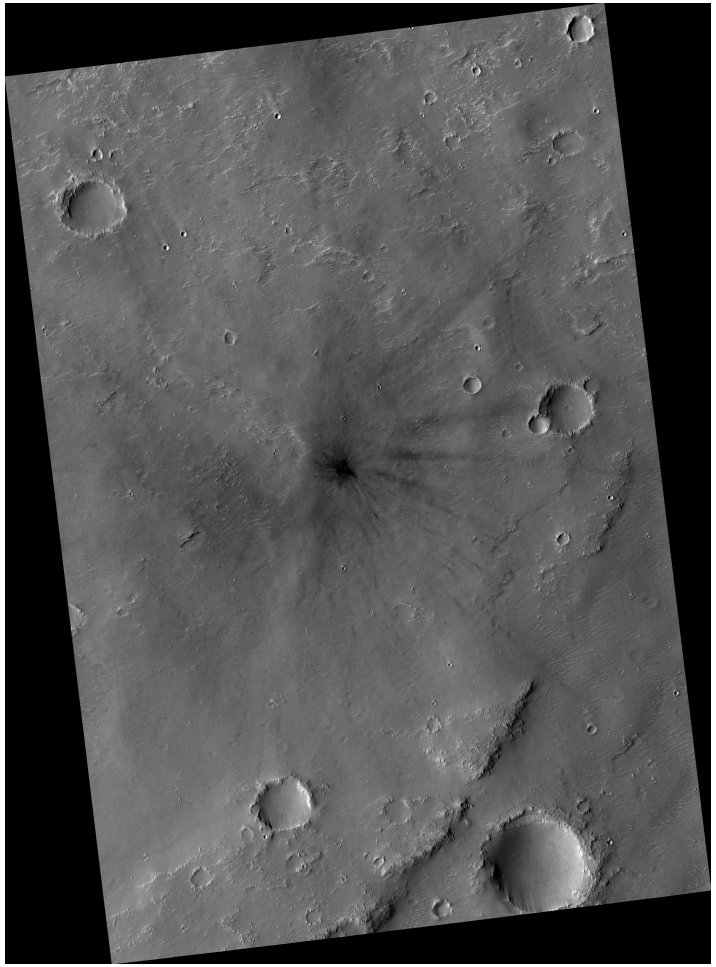
- This data set contains a total of 73,031 landmarks. 10,433 landmarks were detected and extracted from 180 HiRISE browse images, and 62,598 landmarks were augmented from 10,433 original landmarks. For each original landmark, we cropped a square bounding box that includes the full extent of the landmark plus a 30-pixel margin to left, right, top and bottom. Each cropped landmark was resized to 227x227 pixels, and then was augmented to generate 6 additional landmarks using the following methods:
  - 90 degrees clockwise rotation
  - 180 degrees clockwise rotation
  - 270 degrees clockwise rotation
  - Horizontal flip
  - Vertical flip
  - Random brightness adjustment

Salience Detection

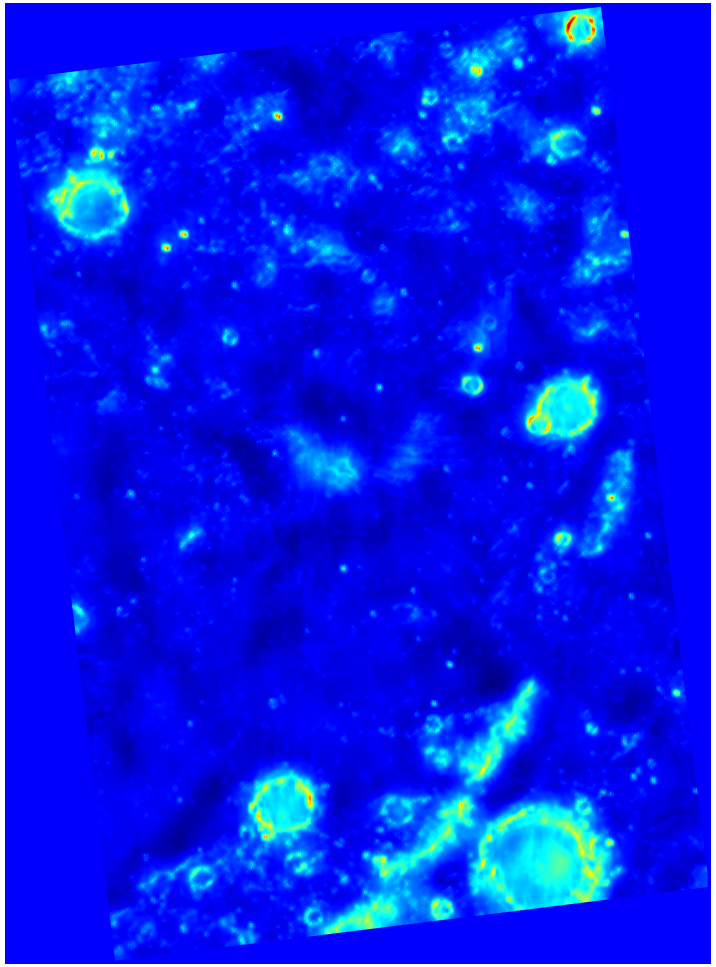


Which is the most unusual fish compares to the others?

HiRISENet Salience Detection



HiRISE map projected image

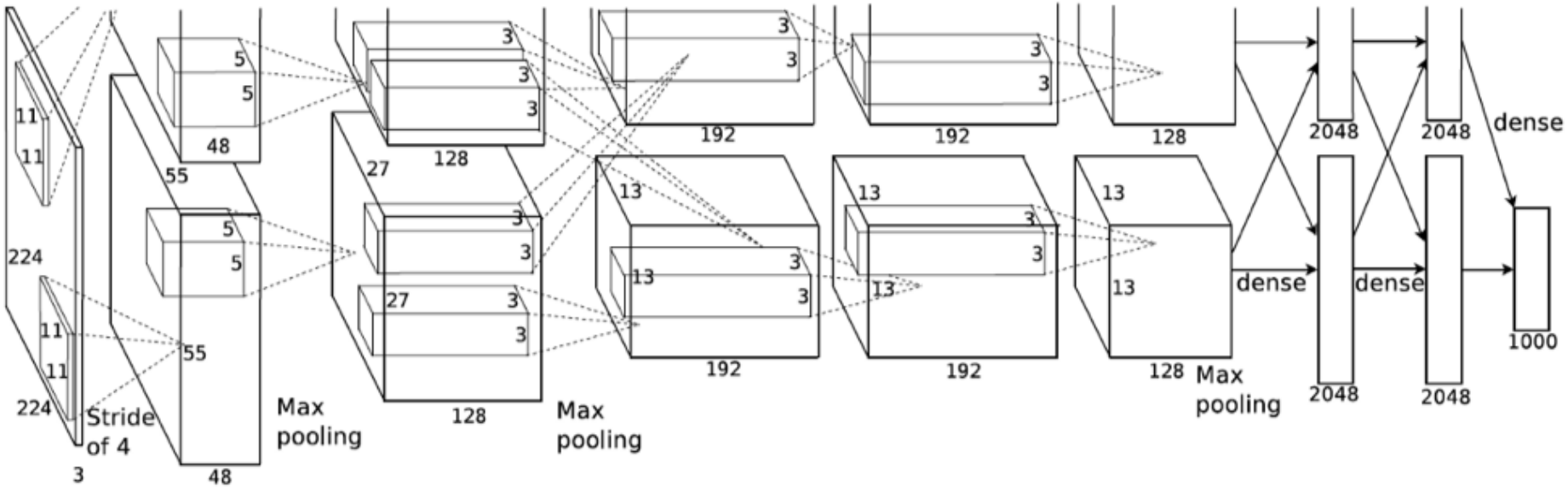


Salience map

Landmarks

Fine-tuning

- Strategy
  - Employ thousands of labeled PDS images
  - Freeze or allow small variations on the weights for initial layers.
  - Boost learning rate on the last layer.

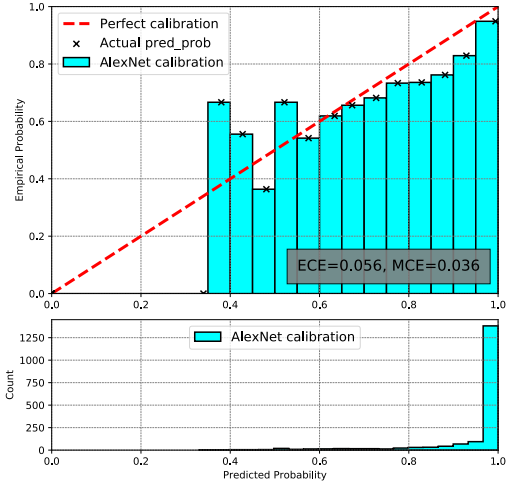


[Alex Krizhevsky, et al, ImageNet Classification with Deep Convolutional Neural Networks, NIPS 2012]

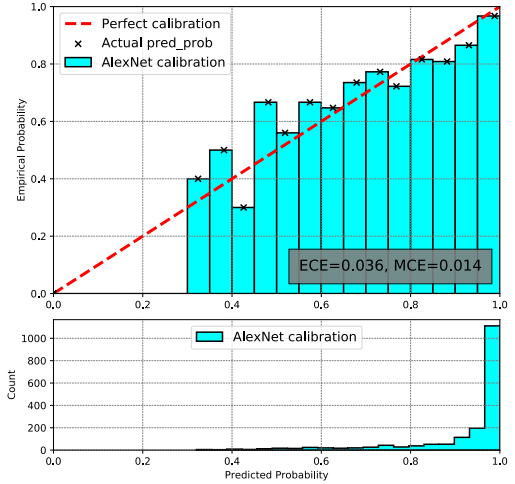
HiRISENet Calibration

Methods	Test accuracy	Test accuracy with 0.9 confidence	ECE	MCE
Uncalibrated	90.00%	93.45%	0.056	0.036
Temperature scaling	90.00% (same)	93.46% (0.01% ⬆)	0.036 (0.02)	0.014 (0.022 ⬆)
Vector scaling	88.40% (1.6% ⬇)	92.13% (1.32% ⬇)	0.035 (0.021 ⬆)	0.013 (0.023 ⬆)
Matrix scaling	89.01% (0.99% ⬇)	92.82% (0.63% ⬇)	0.048 (0.008 ⬆)	0.012 (0.024 ⬆)

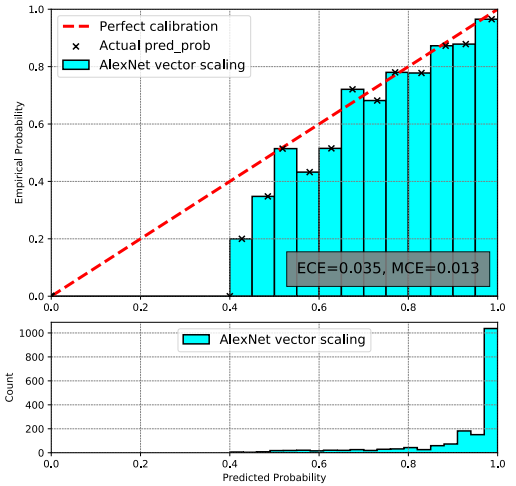
BEST for MRO HiRISE data set!



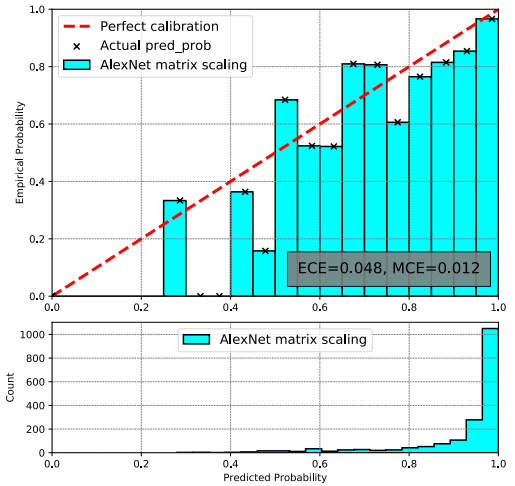
Original reliability diagram



Temperature scaling reliability diagram



Vector scaling reliability diagram



Matrix scaling reliability diagram

[Chuan Guo, et al, On Calibration of Modern Neural Networks, ICMP 2017]